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Report No. IITRI - V6123 - F

MISSION ANALYSES FOR MANNED
FLIGHT EXPERIMENTS

Shuttle Sortie Payload Office
Physics and Astronomy Directorate
National Aeronautics and Space
Administration
Washington, D.C. 20456

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FOREWORD

This final technical report has been prepared for National Aeronautics and Space Administration Contract Number NASW 2259, "Mission Analyses for Manned Flight Experiments." The report presents significant elements of the major analyses performed under this contract. The section on comets and asteroids was a special in depth study performed by Dr. Clark Chapman, IITRI, Tuscon, Arizona. The section on management issues was prepared under a purchase order by OMR, Inc. of Silver Spring, Maryland.

The continued support and assistance provided by Mr. Roland Chase throughout the program is recognized and appreciated by the program staff.

1. INTRODUCTION

The purpose of this report is to document the activities involved in the conduct of NASA Contract NASW 2259, "Mission Analyses for Manned Flight Experiments." Presented herein are selected results of four major investigations conducted during the contract period, June 30, 1971 to December 31, 1972.. These investigations were the development of a high altitude aircraft program plan, an analysis of manned comet and asteroid missions, the development of Shuttle Sortie mission objectives and an analysis of major management issues facing the Shuttle Sortie.

In the following sections, portions of the documents prepared are presented. Programmatic data such as flight schedules and detailed budget data are deleted though such material was generated and analyzed during the program.

2. HIGH-ALTITUDE AIRCRAFT EXPERIMENTS PROGRAM

2.1 Introduction

The purpose of this analysis is to outline a plan defining a Physics and Astronomy Program for the U-2 aircraft. The concept is based upon a strategy which moves from stated objectives, through appropriate parameters and measurements, to potential instrument types suitable to the characteristics of the high-altitude aircraft. The plan is compatible with that propounded by Ames Research Center, "NASA Earth Resources Aircraft Program, Management Plan," dated April 1, 1971.

Aircraft are useful platforms for conducting certain types of physics and astronomy experiments. These vehicles supplement ground-based rocket, balloon, and spacecraft tests as described in the NASA report, "Airborne Research - Ten Year Plan," August 1969. A one page summary of the role of aircraft is given in Figure 1. Figure 2 illustrates the observational capabilities of aircraft using the electromagnetic spectrum as a basis.

The several types of aircraft utilized by NASA have specific advantages. The Convair 990 has proven to be a flexible workhorse and the C-141 will permit flights of heavier instruments such as a 36-inch telescope. The Learjet has capability for higher altitude than the Convair 990 but has limited endurance.

Altitude is very important for physics and astronomy measurements because the atmosphere interferes with the observations. Applicable characteristics of the atmosphere are given in Appendix A where it can be seen that above about 16 km the water vapor is negligible. Since this is the main constituent which restricts ground based measurements in the infra-red, flights above 16 km permit observations which have opened new horizons to astronomers. Infra-red stellar, galactic, and solar system observations have revealed exciting new phenomena.

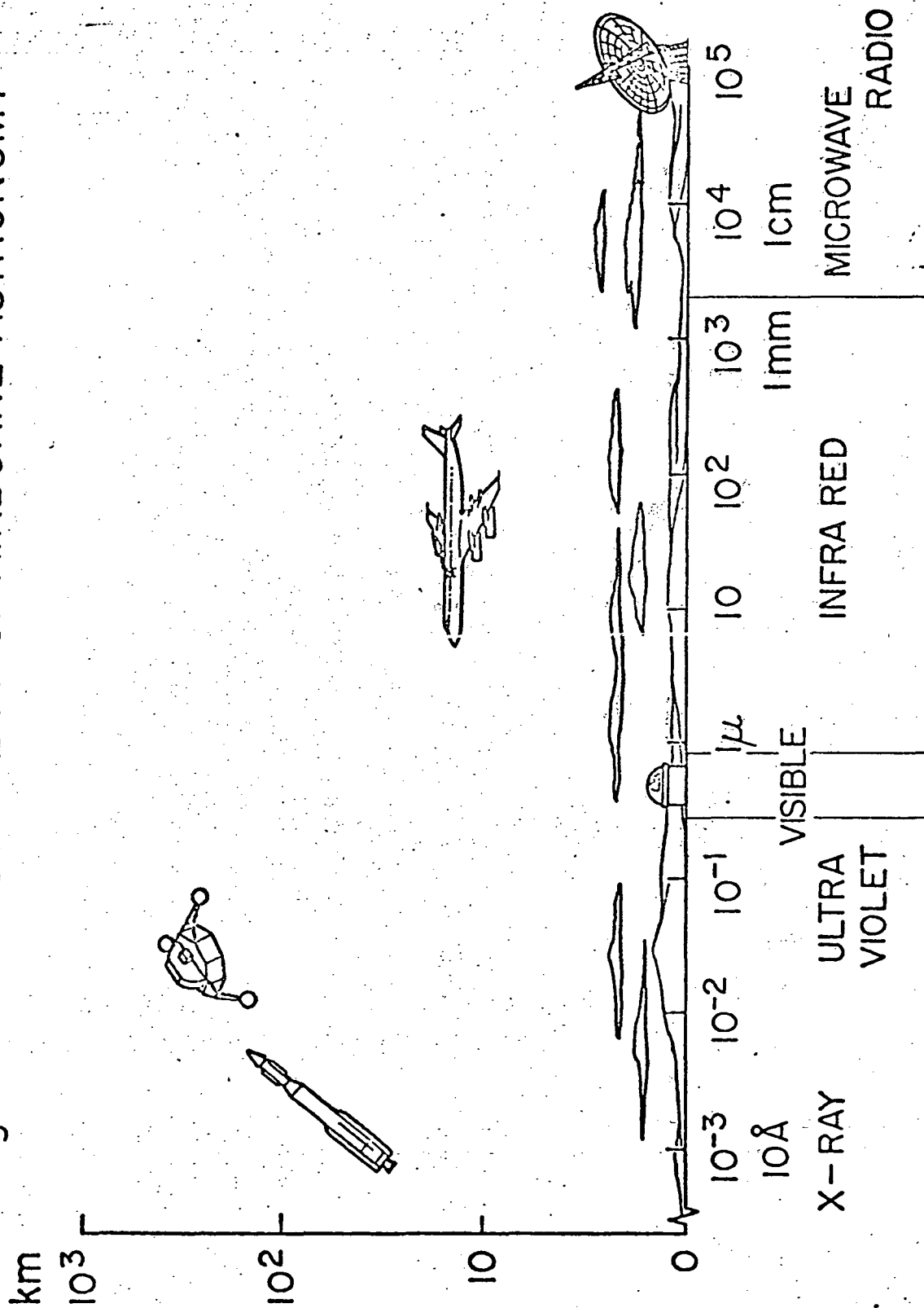
Another constituent of the atmosphere which limits ultra-violet ground based observations is ozone. As can be noted from Appendix A, ozone is a problem all the way up to 50 km, but at 21 km approximately 35% of the ozone layer has been eliminated. However, observations below about 2900 Å are still limited.

In view of this dependence upon altitude, consideration has been given to a very-high-altitude aircraft, viz., the U-2. Characteristics of this aircraft are given as unclassified information in Janes, "All the World's Aircraft." With an altitude capability of about 21 km (70,000 feet) and a payload of about 400 pounds, the aircraft has promise for extending the observational and experimental capabilities over other types of aircraft. Some of the advantages are listed in Figure 3.

Figure 1: Advantages of Airborne Research

- A. Compared to balloons, rockets, satellites
- Relatively short-notice, inexpensive operation
 - Large payload capability
 - Abundance of electrical power
 - Personnel aboard for decision, repair, adjustment
 - Completely recoverable system
 - Feasibility of changing mission profile in flight
- B. Compared to ground
- Mobility, choice of geographical location, variable altitude
 - Speed (extension of observation time)
 - Freedom from overhead cloud cover
 - Feasibility of following meteorological conditions of interest
 - Reduced sky brightness (or temperature) and scattering
 - Improved atmospheric transmission
 - Reduced line broadening and bending
 - Realistic platform for certain space station simulation requirements

Figure 2-APPLICABILITY OF AIRBORNE ASTRONOMY



PARAMETER	PRESENT AIRCRAFT	U-2	SATELLITE
AUTOMATED OPERATION	NO	TO A LARGE EXTENT	YES
SPACE ENVIRONMENT	NO	VERY CLOSE	YES
WEATHER DEPENDENT	YES	MUCH LESS	NO
SIMILARITY OF DATA QUALITY	NO	MORE SO	YES
SIMILARITY OF DATA-MANAGEMENT PROBLEMS	NO	YES	YES
VIEWING THROUGH ATMOSPHERE	70%	90%	100%
DAILY SERVICING	YES	YES	NO
REAL-TIME DATA RETRIEVAL	NO	NO	YES

FIGURE 3
PARAMETER COMPARISON CHART

OBJECTIVES

1. SUPPORT THE NATIONAL PROGRAMS
OF ASTRONOMY AND ATMOSPHERIC
SCIENCES
2. PROVIDE EXPLORATORY AND SURVEY
OBSERVATIONS TO BETTER DEFINE
SUBSEQUENT SPACECRAFT EXPERIMENTS
3. CONDUCT PROTOTYPE TESTS OF
SPACECRAFT INSTRUMENTS
AND OPERATIONS

FIGURE 4.

2.2 OBJECTIVES

Long-Term Objectives

The objectives of the U-2 Program in the fields of physics and astronomy may be grouped into three areas, Figure 4. First is support of the national programs of Astronomy and Atmospheric Sciences. The key paper for this area is the one issued by the Astronomy Missions Board.¹⁾ A second objective is to provide exploratory and survey observations to better define subsequent spacecraft experiments. Since the emphasis will be on infrared observations, further inventoring of sources and characteristics will be made. The third objective is to conduct prototype tests of potential spacecraft instruments and to develop appropriate operational procedures. In particular, potential instruments can be tested and modified much more readily in the aircraft than in spacecraft.

Disciplinary Goals

As the Astronomy Board stated, "Small telescopes in small jets than can reach 50,000 feet should be made available as a standard item for development of new programs. The provision of a 36-inch aircraft telescope now planned is a major step. Some reservations remain whether the Convair 990, the currently planned carrier can fly high enough for certain classes of observation. A program of small jet aircraft observations should be planned to obtain statistical data on the

¹⁾ "A Long Range Program in Space Astronomy," NASA SP 213, July 1969.

quality of various kinds of observations made from altitudes between 35,000 and 50,000 feet at different latitudes."¹⁾

Hence, in the astronomy area, the disciplinary goals may be considered to be stellar evolution, galactic observations, and solar system measurements, Figure 5. In the area of stellar evolution, infrared measurements should be made relative to star formation and aging and emission lines in the far infrared for HI regions of inter-stellar matter. The galactic IR surveys would be to map sources. In the area of solar systems observations, infrared measurements of planetary atmospheres in the outer layers of the sun would be valuable.

"The space between the stars of our galaxy contain vast quantities of diffuse matter--very rarified gas and fine dust. This matter constitutes an appreciable fraction of the total mass of the galaxy. From it form new stars. Despite its quantity and pervasiveness, however, this inter stellar matter can be detected only by its emission or absorption of radiation. ----Such (infrared) observations are valuable, not only because they allow us to detect molecular hydrogen in dense dust clouds that cannot be studied in the far ultra violet, but also because they allow us to directly observe gas-dynamic processes in the inter stellar medium (such as shock fronts, gravitational collapse, etc.,)." ²⁾

1) Ibid, p. 87.

2) George R. Carruthers, "Inter-stellar Molecules,"
Astronautics and Aeronautics, April 1971, p. 16ff.

Accordingly, this memorandum explores the types of objectives, measurements, and instruments which might be appropriate for a U-2 flight program. Both technical and management aspects are considered. It should be noted that the aircraft will be used by other NASA activities and the schedule of availability is still to be determined.

DISCIPLINARY GOALS

Astronomy

- Stellar Evolution: IR measurements relative to to star formation and aging; emission lines in far IR for H I regions of interstellar matter.
- Galactic: IR surveys and mapping of sources.
- Solar System: IR measurements of planetary atmospheres; outer layers of sun.

Atmospheric Science

- Measure the radiation balance at various wavelengths.
- Determine atmospheric constituents at various altitudes, locations, times.
- Measure stratospheric pollutants.

Intermediate Engineering and Operational

- Verify the installation and instrument operation.
- Determine the local "atmosphere."
- Check the stabilization, pointing, and navigation interfaces.
- "Obtain statistical data on the quality of various kinds of observations" (Astronomy Missions Board 7/69).

FIGURE 5.

A second major area relates to atmospheric sciences or aeronomy. The disciplinary goals in this area are related to the radiation balance, determination of atmospheric constituents, and measurement of stratospheric pollutants.

Radiation balance measurements are of interest to those engaged in studies of the sun, the ionosphere, and the weather. Associated with studies of the energy transfer are considerations of atmospheric constituents which affect the transfer. Measurements of the constituents should be made at various altitudes, locations, and times of the day.

The 1970 summer study of critical environmental problems (SCEP) examined several of these areas in its report, "Man's Impact on the Global Environment." Some of the recommendations included, "We recommend extending and improving solar radiation measurements. ---We recommend beginning a continuing survey, with ground and aircraft sampling, of the atmosphere's content of particles and of those trace gases that form particles by chemical reactions in the atmosphere. ---We recommend continuous measurement and study of the carbon dioxide content of the atmosphere in a few areas remote from known sources for the purpose of determining trends. Specifically, four stations and some aircraft flights are required."¹⁾

¹⁾ M.I.T., "Man's Impact on the Global Environment," Summer Study of Critical Environmental Problems, pp. 12 and 14.

Recently there have been indications of concern relative to the long term trends in some atmospheric constituents, in part based on the continued pollution of the atmosphere. Two of the key factors are long term variations in water vapor and in ozone. Hence, high altitude measurements of these constituents over a period of years would be very important to determine trends.

Before embarking on a major program of astronomy and atmospheric sciences observations, it is important to determine quantitatively the capabilities of the instrumentation in the particular platform (U-2). Hence, the first step in the program is to conduct engineering and operational experiments. Using typical prototype instrumentation appropriate for astronomy and atmospheric sciences, this phase would have the following goals: instrument installation and checkout; measurement of the local "atmosphere" around the aircraft; stabilization, pointing, navigation interfaces (the need for a stable table); and statistical data on observation quality. Initial flights emphasizing this disciplinary goal would be advantageous from a management point of view as well as a technical point of view. Appropriate instruments could be selected which have already been flown to aid in the calibration prior to the official acceptance procedure for scientific experiments.

2.3 MEASUREMENTS

The disciplinary goals of the prior section have been examined in more detail to determine what parameters should be examined in order to achieve the goals and then what measurements would be appropriate relative to the parameters. These are summarized in Figures 6, 7 and 8, where typical representative information is provided. Of course, when actual proposals are received from principal investigators, the specific information will be more precise.

Astronomy

In the area of stellar evolution, it can be seen that star formation and star aging are of particular importance and for these areas the object size, chemical composition and temperature are important parameters. Photometers and spectrometers are useful for these parameters. In the area of interstellar matter, again temperature, density, composition, and physical state are the key parameters of interest. Since these are emission line measurements, spectro-photometers are a key type of instrument.

Relative to surveys for new galactic sources, it is important to know the location of the source, the luminosity, and possible time variation. Hence, for infrared measurements in the 20-500 microns region, a photometer would be appropriate. In the area of cosmology, it is hoped to estimate some of the motions of our galaxy, using faint background fluxes and trying to determine the origin of anisotropics by means of a photometer. This same instrumentation can also be employed

PROGRAM STRATEGY - ASTRONOMY

<u>OBJECTIVE</u>	<u>PARAMETER</u>	<u>MEASUREMENT</u>	<u>INSTRUMENT</u>
<u>Stellar Evolution</u>			
Star Formation and Star Aging	Object size Chemical Comp. Temperature	Photometry $\lambda/\Delta\lambda \approx 2-10$	Photometer (IR) Spectrometer (IR)
Interstellar Matter	Temperature Density Composition Physical state	C II, Si II ($5\mu\text{m}-500\mu\text{m}$) Emission Lines Molecular hydrogen	Spectrophotometer
<u>Galactic</u>			
Sources (new)	Location Luminosity Time variation	20-500 μm IR, may peak at 100 μm	Photometer (IR)
Cosmology	Motion of our galaxy	Faint background fluxes, origin of anisotropies	Photometer (IR)
<u>Solar System</u>			
Planetary Atmosphere	Composition	Photometry $\lambda/\Delta\lambda \approx 100$ Emission Lines	Photometer (IR) Spectrometer (IR)
Outer layers of sun (analogy to stellar atm)	Transitions (thermal)		Spectrometer (IR)

FIGURE 6

for the solar system observations which would be related to planetary atmospheres and sun measurements. Possibly the composition and thermal transition should be observed, again using emission line spectrometers.

Atmospheric Sciences

The three objectives in the atmospheric sciences are: radiation balance, atmospheric constituents, and stratospheric pollutants. The key parameters are different but in the case of the radiation balance it is input energy at various wavelengths and chronological variation as well as geographic variation. It is suggested that infrared measurements be made with the calibration checks in the visible and ultra violet using photometers, radiometers, and spectrometers.

The atmospheric constituents and stratospheric pollutants are similar as far as parameters and measurements are concerned. The parameters in both cases are particle size and type, the particular molecules, the density, temperature, and radiance. The difference between these two objectives is more related to the type of constituents being measured. In the case of general atmospheric science, the measurements can be made either by scattering or by collection and the key elements to be measured are such things as ozone, water vapor, molecular oxygen, molecular nitrogen, carbon dioxide, and perhaps argon and helium, using spectrometers and a mass spectrometer. The stratospheric pollutants of interest are sulphur oxides, nitrogen oxides and ammonium sulphates. Again the spectrometer and mass spectrometer are appropriate instruments.

PROGRAM STRATEGY - ATMOSPHERIC SCIENCES

<u>OBJECTIVE</u>	<u>PARAMETER</u>	<u>MEASUREMENT</u>	<u>INSTRUMENT</u>
Radiation balance	Input energy at various wavelengths and times and US locations	20-500 μ m IR with calibration checks in uv, visible and near IR	Photometer Radiometer Spectrometer
Earth Atmospheric constituents	Particle size and type; Molecules; Density, temperature, radiance	Scattering and collection; ozone, water vapor, O ₂ , N ₂ , CO ₂ , Perhaps argon and helium	Spectrometer Mass spectrometer
Stratospheric pollutants	Particle size and type; Molecules; Density, temperature, radiance	Scattering and collection; SO _n , NO _n , NH ₃ SO ₄	Spectrometer Mass spectrometer

FIGURE 7

Engineering and Operational

Concerning the engineering and operational measurements that need to be made initially to determine the effectiveness of the instrument-platform combination, the objectives can be divided into: instrument installation; local "atmosphere"; stabilization, pointing and navigation interfaces; and statistical data on observation quality. As shown in Figure 9, the appropriate parameters for the instrument installation are, what size can be installed; what about frosting of the optics and equipment (thermal problems); what power is required and available; what are the recording requirements; and what controls are needed? Since this is a one man aircraft, the instrumentation will have to be operated from the cockpit. These relate to electrical, electronic, optical, and pneumatic measurements for both checkout and flight safety.

It is not expected that the local atmosphere will be sufficiently adverse to inhibit these measurements, in view of the tenuous nature of the atmosphere and the fact that the engine exhausts behind the location where the measurements will be made. Nevertheless, it is important to have some quantitative indications of what the atmosphere is. This could concern such things as boundary layer thickness, composition, and transparency in the infrared. The measurements might include calibrations or various wavelengths and distances from the skin using known objects for calibration.

PROGRAM STRATEGY - ENGINEERING AND OPERATIONAL

<u>OBJECTIVE</u>	<u>PARAMETER</u>	<u>MEASUREMENT</u>	<u>INSTRUMENT</u>
Instrument installation	Size, frosting, (thermal) power, control, recording	Electrical, electronic optical, pneumatic check out	IR telescope system, atmospheric instrument (spectrometer)
Local "atmosphere"	Boundary layer thickness, composition and transparency in IR	Calibrations at various wavelengths and distances from skin	Photometer, spectrometer
Stabilization, pointing navigation interfaces	Aiming and location accuracy, rate, hold, recording	Independent check of pointing and location	Photograph star fields & earth sites
Statistical data on observation quality	Repeated measure- ments of radiance, composition vs. time and location	Using a known stellar source, measure at various times of day and parts of the U.S.	IR Photometer Spectrometer

FIGURE 8

CANDIDATE INSTRUMENTS - ENGINEERING AND OPERATIONAL PHASE

<u>DESCRIPTION</u>	<u>TYPE</u>	<u>SOURCE</u>	<u>PRIOR TESTS</u>	<u>PHYSICAL CHARACTERISTICS</u>	<u>DETECTION CHARACTERISTIC</u>
<u>Astronomy</u>					
IR Telescope (photometer? spectrometer?)		Low Arizona	Flown on Learjet		
IR Telescope (Photometer? Spectrometer?)		USAF/W-P (Autonetics)	Flown on U-2		
<u>Atmospheric Sciences</u>					
SIRS Spectrometer	IR Spectro-meter (Rotation sp. Water vapor)	Gebbie - NES	Nimbus Convair 990		
IR Temp Profile					
HRIR			Nimbus		
NACE	Mass spec-trometer-atmos. molecules	Newton/Rely Goddard	San Marco - C		
IRIS	Inter-ferometer/spectrometer	Hanel Goddard	Nimbus		7-22 μ m

FIGURE 9

In the area of stabilization, information is required relative to how the aiming will be done; what is the location accuracy so that the flight mission planning can be done; what is the stability of the aircraft both as to rate and holding ability? In the Learjet, the initial infrared telescope instrument was mounted on a roll-stabilized platform and it is planned that subsequent measurements will be performed on a platform having stabilization in two dimensions. The measurements can be made using ground-based observations for locations and using stellar positions to check the pointing and roll control. A typical modus operandi would be to employ cameras to photograph star fields and earth sites.

The last objective, statistical data on observational quality, necessitates repeated measurements of radiance and composition versus time and location. And again, using known stellar sources, measurements would be made at various times of the day and over various parts of the United States, using IR photometers and spectrometers. This work would be accomplished prior to detailed stellar observations. In the Learjet, it is standard procedure to make some calibrations based on a known planet prior to making the stellar and galactic observations.

3. USES OF THE SPACE SHUTTLE FOR STUDYING ASTEROIDS, COMETS, AND INTERPLANETARY DUST

3.1 Introduction

After the space shuttle is developed and becomes available for use in the sortie mode, there are many possible uses to which it can be put for studying minor objects and dust in the solar system and in the near-earth environment. Since it is pointless to duplicate the kinds of observations and measurements which can be done from ground based observatories and in laboratories, let us first outline the advantages that can be obtained from near-earth space.

- greater wavelength range available, ranging from the far UV through IR and microwave regions inaccessible from beneath the earth's atmosphere
- little or no contamination from terrestrial light sources, including airglow. (This assumes no appreciable contamination by shuttle effluents.)
- direct accessibility to particles of interest (meteroids, interplanetary dust) before their entry into the atmosphere.
- different vantage point for observations (e.g. most or all of the sky; observations close to the sun; observations of meteors from above.
- location in interplanetary environment suitable for experiments (in solar wind, vacuum, zero-gravity, etc.)
- better angular resolution for telescopic observations (i.e. perfect "seeing", telescope diffraction limited).

Needless to say, a small un-manned orbiting satellite

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would theoretically benefit from the same situation. While experiments similar to experiments currently being performed or being planned from orbiting astronomical, solar, or geophysical observatories could also be done from a shuttle base, or from sub-satellites or vehicles deployed from the shuttle, the clear interest is to identify studies which can perhaps be done more readily, or maybe even exclusively, from the shuttle.

It should be pointed out, therefore, that observations and experiments performed from the shuttle differ in the following major respects from satellite experiments. Since man is aboard and can be utilized in the experiments, and heavy payloads can be delivered to earth orbit, experiments or observations can be somewhat more ambitious and complex. On the other hand, projects involving long-term monitoring of space parameters are not suited to shuttle flights of limited duration.

In the sections which follow, we give emphasis to those studies which are best accomplished from shuttle. However, others are discussed which might as well alternatively be done from unmanned earth satellites or by using other methods. Therefore, while some of the proposed experiments may justify the need for a shuttle sortie-mode scientific laboratory, others are merely examples of kinds of experiments which could be done from the shuttle once it exists but do not, in and of themselves, justify such a shuttle development. The exact demarcation between experiments which require shuttle versus those which simply could make use of shuttle is difficult to draw at this time, since it depends on advancing technology and evolving scientific requirements.

3.2 STUDIES OF ASTEROIDS FROM SHUTTLE

The asteroids are located in orbits primarily between Mars and Jupiter. A few asteroids (including some of high scientific interest) occasionally pass very near the earth. All asteroids are sufficiently small, and distant, that there is virtually no spatial resolution possible from earth-based telescopes. Studies of asteroids to date fall roughly into two categories: (1) discovery of asteroids, orbit determination, and analysis of the dynamical properties of the ensemble of asteroids; (2) physical studies of asteroids, including size, shape, spin, color, surface composition, etc. Much work is needed in both areas in order to properly prepare for possible asteroid space missions which may fly within a decade.

The aim of studies of asteroids is to determine their origin, relationships to each other (e. g. fragments), and relationships to other bodies in space (comets, meteorites). In comparison with studies of comets and interplanetary dust, the availability of the shuttle is of less critical importance. Nevertheless, there are several interesting experiments possible.

High Resolution Studies

The very largest asteroids approach one second of arc in diameter. Most of even the larger and more important asteroids are only a few tenths of a second in diameter or smaller. It is impossible, therefore, to measure the sizes of these asteroids directly from ground-based observatories, let alone study their shapes, surface markings, etc. From above the

earth's atmosphere, such spatially-resolved investigations become at least marginally possible for perhaps several dozen asteroids. A telescope with minimum aperture of 1 meter (preferably much larger) is required; for diameter measurements an optical interferometer might be still more useful. With high quality optics, moderately reliable direct diameter measurements could be made--of sufficient reliability to serve as a check of the indirect infrared thermal emission techniques recently applied from the ground. Obviously elongated shapes might be detectable for some asteroids, and spatially resolved studies of surface markings might be possible for a few of the largest (although the scientific utility of such studies may not be high).

Especially during the close approach of an Apollo (earth-orbit-crossing) asteroid, such detailed physical observations may be of considerable value--especially if coordinated with ground-based studies of light-curves, brightness, etc.

Expanded Wavelength Data

Asteroids are apparently rocky bodies made out of minerals. There is a possibility that some may be metallic or icy. There may, indeed, be a number of dead comet nuclei, or nearly-dead nuclei. In examining spectra of asteroids, therefore, one is primarily interested in the reflection spectrum which may be expected to show the broad, featureless solid-state absorptions due to electronic transitions and charge transfers in mineral (and ice) crystals. No sharp molecular

emission features, common for comets, have been found yet, although they may be present in a minor way and -- if found -- would be important discoveries.

Although the most useful part of the reflection spectrum-- from the point of view of mineralogical identification -- is accessible from earth, it can be more easily observed from above the earth's atmosphere. This is the region from about 0.8 to 2.4 microns, a region in which there are important absorptions, especially for pyroxenes. The visible is, of course, well observed from earth, but there are certainly useful spectral data to be obtained in both the far UV and farther into the infrared. Thermal IR radiometry may be more precisely carried out from above the earth's atmosphere as well.

Integrated Asteroid Belt Data

There is little utility to using the shuttle to discover additional asteroids or for astrometry. Nevertheless, the gross characteristics of the asteroid belt--especially at smaller sizes than currently measured--may be studied in several fashions. It is possible that a new study, somewhat akin to the Palomar-Leiden survey, might be carried out from earth orbit in an attempt to extend the diameter-frequency relationship to smaller sizes and to study the dynamical properties of smaller bodies. The utility over ground-based studies may only be slight, however.

More important are studies of the distribution of small particles and dust in the asteroid belt through photometry of the zodiacal light. Such studies, which are directly applicable to

problems of accretion and fragmentation of asteroids and the evolution of the small-particle population in the asteroid belt, are discussed in more detail in the section on dust.

Operational Remarks

Asteroids are faint objects, which move reasonably rapidly against the star background. Most asteroids of interest are 10th, 11th, or 12th magnitude, or fainter, and move fractions of a degree per day. The predictions are sometimes poor. Therefore finding asteroids can be difficult. The presence of a trained man on board shuttle would certainly enhance the probabilities of finding an asteroid as opposed to using automated schemes. The kinds of astronomical equipment required for asteroid observations should not impose constraints on the shuttle, other than the requirements for a large telescope, easy access to the sky in most or all directions, and adequate stability.

3.3 STUDIES OF COMETS FROM SHUTTLE

Comets are sometimes the largest objects in the solar system. But, with the exception of their nuclei which are of undetermined size, they are extremely tenuous. Current models for comets generally consist of a small solid nucleus appropriately composed of ices and silicates so as to give rise to the observed coma and tail when heated during close approach to the sun. While the nucleus is the source for the gases and plasmas, the detailed structure and behaviour of the visible comet is controlled by the solar wind, magnetic fields, and radiation environment in the inner solar system.

The origin and detailed nature of cometary nuclei are not at all understood, and a minority of investigators even doubt the existence of a cohesive nucleus. While the chemical composition, and state of ionization, of the comet heads and tails are roughly known, the detailed nature of the interaction with the space environment is still unknown. The relationships of comets to Apollo asteroids, meteor streams, and related phenomena are still matters of considerable dispute. Progress has been made in understanding the observed differences between new and short-period comets, and observed evolutionary changes in comets (including secular changes in their orbits and break-up during close solar passages), are widely accepted. The implications for the detailed processes of jetting and structure of the nucleus are still uncertain, however. The mode of formation (and even location of formation) of comets is still a matter of conjecture, and estimates of typical cometary lifetimes and of the numbers of dead comets are shaky. There is much continuing research on the dynamical influences on comets of the planets.

There are two fundamental approaches to studying and understanding comets and solar system processes which affect them. The first is through astronomical observations: spectroscopy, astrometry, photometry, structural studies, etc. These have mostly been carried out from ground-based observatories, but a few significant observations have been made from space. The second approach has remained untested and is a particularly fruitful area for shuttle research: the creation of a model, artificial comet and close studies of it from the physico-chemical point-of-view.

Astronomical Observations

Photometry

It is important to understand all the phenomena which give rise to the coma and the plasma and dust tails: vaporization and release of materials from the nucleus, the dynamical and magnetic processes which remove these materials from the vicinity of the nucleus and eventually from the comet itself, and the physical processes (such as molecular collisions) which ionize and otherwise change the physical state of these materials (e.g. the production of radicals from their supposed precursors).

In order to do this, one desires two-dimensional photometry of the comet head at high spatial resolution, in a suite of appropriately selected monochromatic wavelengths (chosen so as to observe the various identified radicals and other components of a comet singly). Sensitivity should be high for those components with weaker lines but which may be among the most abundant or important constituents of a comet. A time resolution as short as minutes may be useful to detect time variable phenomena.

It is particularly important to observe changes as a function of the comet's heliocentric distance and as a function of distance within the comet from the nucleus.

High Resolution Structural and Dynamical Studies

With order of magnitude increase in effective resolving power, it is possible to make great strides in observing detailed cometary structure. Such studies should be done not only in the visible, but in some carefully selected and

reasonably bright emission lines. Heterogeneity in the head is of particular interest, especially if it can be tied down to jetting processes on the nucleus. Structural details of the envelope (contact surface between the solar wind and the cometary plasmas) are especially important.

The changes in cometary structure as a function of time, indicative of the dynamical forces and processes in a comet, are poorly measured at present. What is required to improve this situation is a program of imaging cometary structure with high spatial resolution (especially for the head) and with high quantum efficiency so as to maximize time resolution. If such measurements can be carried out continuously for periods of days or weeks, much better pictures of cometary dynamical processes can be obtained than is possible from terrestrial photographs. In the terrestrial case, gaps in coverage are produced by daylight hours or clouds from a single station and observations from multiple stations around the globe generally lack uniformity.

Of critical importance are measurements of the shape, size, and character of the solid nucleus (if any). If such a nucleus can be identified, it would be useful to make detailed measurements of it similar to those made of asteroids (light-curve, spectrophotometry in the near IR and visible, etc). In order to do this, it is necessary to exclude as much light from the coma as possible, by using a very small aperture and guiding carefully. Seeing conditions may prohibit such observations from the earth.

Studies of Sun-grazing Comets

On rare occasions, comets pass very close to the sun-- most recently the famous comet Ikeya-Seki in 1965. These comets are of special importance because they are heated to much higher temperatures than is usual, and one has the opportunity to study lines and species of molecules not usually accessible which should provide valuable clues to the nature of the ices and clathrates which comprise the cometary nucleus.

Also of great interest are the frequent occasions when such sun-grazing comets are broken apart by tidal forces near the sun. Detailed structural measurements of the cometary head are thus very revealing about the actual processes of jetting or actual break-up of the comet.

Unfortunately, during the critical time of solar perihelion passage, sun-grazing comets are very difficult to observe from the ground because they are right next to the sun and only their brightest features can be discerned above the background sky brightness. From a shuttle station above the earth's atmosphere the observing conditions could be remarkably improved, especially if a scheme were devised to protect the optics from direct sunlight.

Observations in the Far UV

Recent discoveries of Lyman α halos surrounding some comets point the way toward more refined observations from a stable, sophisticated observatory located on a shuttle platform. There are undoubtedly additional atomic and molecular transitions to be discovered in the far UV. Interpretations of observations

already made by orbiting satellites will point the way to the most fruitful studies in this wavelength region.

Observations at IR and Microwave Frequencies

Spectroscopy in the far infrared, and in near infrared regions seriously affected by terrestrial atmospheric absorptions, could be very important in identifying new components in comets. Some particularly important species, some of which are indirectly suspected to be major components of comets, can be revealed in these wavelength regions. They include methane, ammonia, and water. Of course, once they are identified, it will be interesting to perform more detailed measurements of their temporal and spatial variations, as already described in the section on photometry above.

Photometry of Faint Cometary Structure and Extent

Given a black sky background, it should be possible to measure the faint outer extensions of a comet's coma and tail which otherwise would be masked by airglow. A very fast photographic system could therefore be used to measure structural properties of comets at these low light levels.

3.4 IN-SPACE EXPERIMENTS

Close-up Study of Artificial Comet

The shuttle may provide the first real opportunity to study an artificial comet. The shuttle could lift into earth orbit a sufficiently large mass of ices and rocks, appropriately assembled to model the best guess we now have for the structure of a cometary nucleus, to produce an impressive and representative small comet. The shuttle could then provide the platform, and laboratory facilities, for making close-up

measurements of the comet as it develops and evolves. The actual first-hand testing of one or more model comets could well provide fundamental insight to the nature of cometary processes. It serves the added advantage of providing experience in close-up observation of comets which may subsequently be employed in cometary rendezvous missions.

It is beyond the scope of this report to describe in detail such a complex experiment, but several words of caution are required. First, the current understanding of the composition of the cometary nucleus is probably too poor to build a realistic likeness of a comet nucleus at this time; one expects, however, that by the time such an experiment could be implemented, a sufficiently detailed model will have been determined. The practical problems of building such an object, carrying it into space, and launching it are certainly difficult, especially if the object is to start off with appropriate physical conditions. There also should be careful analysis of the possible interactions between the shuttle and the comet itself; there must be some trade-off between the necessity of getting sufficiently close to the object to make appropriate physical and chemical measurements and avoiding any unnatural influence on the object as it develops.

Such experimentation on the artificial comet in space should be coordinated with ground-based observations of the comet, using traditional techniques, provided it develops to sufficient size. It may prove interesting, once the comet has

reached a state of equilibrium, to disrupt it, propel it closer to the sun, or let it decay into the earth's atmosphere. Such phases of the artificial comet's life can be monitored from the ground.

Release of Cometary Constituents

A simpler class of experiments, which may nevertheless yield important information about processes which affect comets, is the release of various chemical constituents into space, and observation of the resulting cloud from both earth orbit and from the ground. This is much simpler than construction of a model comet and yet may model certain processes occurring, for instance, in comet tails. Elementary experiments of this sort have already been accomplished from both manned and unmanned space vehicles.

Laboratory Physicochemical Studies of Materials in Space

Many physical processes of intrinsic theoretical interest, or of practical interest to understanding comets, can be studied in ground-based laboratories. Others may be aided by one or more of the conditions which exist in space: the good vacuum, weightlessness, the radiation environment, the lack of walls, etc. The production of radicals, important cometary constituents, requires very low molecular collision probabilities. These might best be studied, in a cometary context, in earth orbit. Among processes of interest which could be studied in a space laboratory are the adsorption of gases to ices and the production of clathrates, the interaction of cometary materials

with the solar wind, and problems of accretion/dispersal of dust and ice grains in the virtual absence of a gravitational field.

Some of these uses for the shuttle are more completely discussed in other sections of this report such as the section on magnetospheric physics.

3.5 STUDIES OF METEORS FROM SHUTTLE

Meteors, as usually defined, are the phenomena which occur when a small particle (meteoroid) impacts the earth's atmosphere. Depending on the size of the particle, the phenomena include a streak of light, airwaves, a visible train, a path of ionized particles, sound, and occasionally impact with the ground. A number of techniques are used to study these phenomena from the ground, including visual counting and photography, reflection of radio waves off the trains, spectroscopy etc.

The fundamental problems concerning meteors relate to their origin and associations. It is certain that they come from different sources. Some meteor showers have been identified with swarms associated with dead or dying comets. There are reasons for believing that some of the meteorites (meteoroids which survive passage through the earth's atmosphere) are derived from the asteroid belt, or elsewhere. There are approximately four different approaches to studying meteors: (1) measuring their trajectories so as to determine the statistical characteristics of meteoroid orbits; (2) studies of their magnitude/frequency relation (so as to yield size/ or mass/ frequency relations for impacting particles); (3) measuring

their flight paths and behavior in the earth's atmosphere which yields clues to their density, shapes, and processes which may modify the character of pieces eventually picked up from the ground; and (4) studies of meteor spectra and other parameters related to their chemical composition and physical state and the processes by which they are modified by passage through the earth's atmosphere.

There are several advantages to the study of meteors which can be obtained from an observing platform in earth orbit. We save until the next section, discussion of studies of small particles in space and restrict ourselves here to observations of the meteor phenomena in the earth's atmosphere.

Detection and Monitoring of Meteors

There are some obvious advantages to being located in space above the earth if one wishes to record as complete a sample as possible of meteors. It is not clear that this advantage is critical, but one can certainly observe meteors occurring in a much wider area and with practically no problem of atmospheric extinction or clouds.

Depending upon the orbital period of the shuttle, there is the opportunity for obtaining meteor counts from widely different areas on the earth at fairly frequent intervals using the same instrumentation operating in the same environment. This might permit better definition of the variation in meteor frequencies with radiant geometry, and other factors.

Meteor Spectra

There may well be significant emission lines due to undetected elements in spectral regions not accessible from ground-based observations (UV and far IR). These can well be exploited from a shuttle platform.

Artificial Meteors

The shuttle might provide a platform for both launching and observing artificial meteors.

Coordination with Ground-based and Aircraft Experiments

There is ample opportunity to devise experiments which make use of both the shuttle and ground-based techniques for the study of meteors.

For the determination of meteor orbits and flight paths, coordination between an observatory on the shuttle and ground-based photography of meteors might provide a far more efficient method of obtaining significant numbers of triangulated measurements. Since the shuttle observatory provides wide coverage and virtually continuous observation, no network of ground-based stations is required. The shuttle could provide the necessary second observation for observations made at any single station on the ground.

Such coordinated studies between a shuttle and ground-based meteor observatories might enhance the chances of finding trajectories for more recoverable meteorites. As it stands now, the Prairie Network seems to cover too small an area to provide significant numbers of positive observations. Of course, on balancing out the greater coverage possible with shuttle with the short flight times, the chances for success may remain slim.

It is of considerable interest to capture the meteoritic particles which frequently remain suspended high in the atmosphere in the train of a bright fireball. Correlating physical measurements of the properties of such particulate debris with the spectral and orbital characteristics of the observed meteor provides important insights. Because of the wide coverage possible from shuttle, it should be possible to set up a coordinated program designed to effect as many successful captures of meteoritic debris as possible. With fast communications links with airbases, one could direct suitable aircraft to the position of a visible train left by a successfully observed fireball.

3.6 STUDIES OF DUST AND LIBRATION POINT CLOUDS FROM SHUTTLE

The solar system is filled with a very tenuous distribution of dust. It is of interest to determine the sources for this dust, the sinks, and the processes which affect it. Clearly dust is produced by collisions in the asteroid belt, for instance. Debris left over from comets contributes to the dust population and there is presumably an interstellar component as well. Although most dust in the inner solar system remains there for a period of time short compared with the age of the solar system, due to removal by the Poynting-Robertson effect, light pressure, and other causes, there may be certain places where the dust is dynamically stable and may be a remnant of the original cloud from which the solar system condensed.

The spatial distribution of interplanetary dust should be determined for the clues provided for its evolution, as well as for gauging the necessity for shielding of spacecraft to be sent on different missions. The diameter-frequency relation is of considerable interest, in part for the role the dust plays in impacting and otherwise affecting planetary and asteroidal surfaces. The physical and chemical properties of the dust should also be determined which, along with the orbital properties, should provide clues about the relationship of dust to the asteroids, comets, and other sources.

Interplanetary dust is manifested always by very low surface brightness. The zodiacal light is the most prominent phenomenon ascribed to solar system dust. The gegenschein is appreciably fainter. It is so faint that observers have differed on its critical characteristics and have debated the location of the dust responsible for it. Even the mere existence of faint patches of light located in the directions of the L4 and L5 points of the earth-moon system is in dispute.

The problems with continued studies of interplanetary dust from the ground are the atmospheric extinction and the extraneous sources of light. Given no self-contamination of its local environment, the shuttle would provide a superb observation site for studying such dust, not only with fast astronomical instrumentation but by direct sampling and analysis.

Photometric Studies

We wish to obtain a photometric map of diffuse reflected light from solar system dust down to the faintest light level possible. By making multiple measurements with different

geometries with respect to the earth and the sun, it becomes possible not only to sort out contamination by background starlight (the Milky Way) but to effect some kind of triangulation, as well. Of particular interest are (1) detection of dust clouds in the L4 and L5 libration points of the earth-moon system; (2) detection of other dust concentrations associated with the earth, the moon, and perhaps other planets such as Venus; (3) confirmation of the characteristics of the gegenschein as measured from the ground; and (4) studies of structure and asymmetries in the zodiacal light. Conceivably one could detect meteor streams, very faint comets, and similar phenomena.

Given a sufficient surface brightness level, it should be possible to obtain more refined measurements of the chemical and physical properties of interplanetary dust by observing both polarization and reflection spectrum as a function of the geometry. Conceivably there may be an element of emission recognizable as well. From such observations one can make progress in determining the mineralogy of the dust grains and perhaps their size distribution.

Given adequate advances in laser technology, one may also consider the possibility of "active" photometric studies by substituting a powerful laser for the sun as a source of illumination. In evaluating the feasibility of a laser scattering experiment, the extreme tenuousness of interplanetary dust should be kept in mind.

Direct Sampling and Analysis

A shuttle platform would enable experimenters to capture small dust particles from the near-earth environment for immediate study by on-board laboratory facilities. The advantages over return of dust samples from unmanned satellites is probably small, and it should be recognized that most of the particles collected will have been substantially altered by the capture process, depending on the process used.

3.7 CONCLUSIONS

The study of interplanetary objects and phenomena can certainly be enhanced by studies from a sortie-mode shuttle capable of serving both as an astronomical observatory and as a laboratory for sample analysis. Although many of the goals and projects identified above could be accomplished by other means, there are areas where the shuttle appears to excel. Of highest priority for a shuttle program of study of asteroids and comets are two kinds of measurements: (1) those kinds of astronomical observations which require location outside of the earth's atmosphere (chiefly to achieve greater spectral range) and simultaneously require close monitoring by observers because of the complexity or precision required; and (2) deployment and analysis of an artificial comet and related studies.

The astronomical observations are generally of two types. First are studies requiring high resolving power for detailed spatially resolved observations of distant objects (comets or asteroids). A telescope of one meter or larger, figured to high

optical standards, and capable of retaining such a figure during launch is required. For some kinds of observations, the stability of the observing platform must exceed current specifications for airplane flights. The second kind of observation requires short-focus, wide-angle, "fast" optical systems, capable of studying phenomena of low intrinsic light level over wide angular ranges. In order for these kinds of observations to be successful, all sources of extraneous light (both emitted and reflected) must be reduced to a minimum.

On-board laboratory studies of materials must be restricted to those that require the special circumstances available in the shuttle. Such studies include those requiring a physical environment not reasonably reproducible in a terrestrial laboratory (perhaps the size of the environment, and absence of walls are the chief factors not achievable on the ground). Also, included are studies of evolving physical systems which would otherwise have changed in state by the time the materials were returned to earth and studied in a terrestrial laboratory. The most intriguing kind of laboratory study, and the most complex one we have envisioned here, concerns the analysis of an artificial comet and its associated phenomena. Coordinated astronomical observations, both from a shuttle observatory and from the ground, are an integral part of this project.

Such studies of the interplanetary dust, comets, and asteroids from earth orbit benefit us in two ways: first, for their fundamental additions to our scientific understanding of these objects

and phenomena; secondly, for the insight they provide to be utilized by subsequent space missions. We wish to be sufficiently far up on the "knowledge-curve" about such objects as asteroids and comets before embarking on a difficult space mission to investigate them. Observations from earth-orbit provide much data that cannot be obtained from the ground. Information about interplanetary dust will continue to help us improve the engineering models for the dust distribution which poses a physical threat to space missions, especially through the asteroid belt. Lastly, the experience gained from close-up simulated-rendezvous studies of an artificial comet should prove invaluable for refining actual cometary rendezvous missions being discussed now for the 1980's.

4. ANALYSIS OF SHUTTLE PAYLOAD MANAGEMENT ISSUES

This section was prepared under a purchase order issued to OMR, Inc. of Silver Spring, Maryland.

4.1 Current Situation and basic management issues.

Condition I: Lack of clarity of accountability between OSS and OMF and within OSS among science managers, program managers and OSS staff elements. "Lack of a single authority that centers can deal with who can make program descisions that will stick."

Results: a. Confusion on the part of Center personnel about who they must work with to get required program descision.

- b. Headquarters personnel loss of credibility and Centers less willing to commit or respond to requests from Headquarters.i.e. to develop mission project preliminary definition plans.
- c. Inability to resolve differences among Headquarters staff creating confusion and lack of action of part of Centers.

Action: a. Define Functional accountabilities and inter-relations between OSS and OMSF-Headquarters elements and centers;scientist, engineers and program managers.

- b. Establish the process by which project and functional tasks assignment will be made to Centers and other organizations.

Condition II: Lack of overall Program Plan for the Physics and Astronomy Pay load Program which includes realistically scaped program objectives.

Results: a. Inability to develop the inverse planning process required to meet established time targets, for scientific objective and:

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1. establish priorities of effort for fy-73-75 time frame.
 2. insure appropriate utilization of limited manpower and dollar resources to meet program objectives.
 3. provide justification for Preliminary Analysis and Definition studies required in fy 73-75 time period, if longer range scientific objectives are to be met.
 4. prevent limited dollar resources from being diverted to shorter range non-scientific projects.
- b. Lack of willingness of Centers to commit limited manpower and dollar resources to projects in support of missions that do not stand a good chance of going to Definition and/or Design and Flight Phases.
 - c. Centers are currently setting project priorities by doing their own assessment and making judgements about what will get approved and is likely to be funded.
 - d. Lack of common agreement of priorities for shuttle action between Headquarters and Centers. Headquarters concerned about Center commitment to take project responsibility. Centers concerned because Headquarters has not made clear cut assignments.
 - e. A shuttle craft ready to go and no experiments ready to fly.

Action: Headquarters Program Manager draft an overall program plan and submit it through channel for approval. Until an overall program plan is developed and approved and accountabilities clarified, progress on shuttle projects will be slow.

Condition III: The Scientific Community and apparently many scientists within NASA are not sold on the shuttle programs as being the most useful for them.

Results: a. Resistance within NASA and Scientific Community to change current modes. i.e. balloons, rockets, aircraft, and ground based to shuttle sortie mode.

b. A real concern that current balloon, rocket, and air projects will be curtailed or even cancelled in order to provide money for shuttle if the need for money than programmed is developed.

c. Resistance to the facilities concept because of the lack of understanding or fear on the part of some scientists that they will not personally get to do the hands on experimentation; loss of control of development of equipment; loss of control of data developed; requirement to early on reveal their experimental concept.

d. Increased competition among scientists.

e. Increased difficulty in enticing scientists to dedicate themselves and willingly invest the time required to build the instruments facilities.

Action: a. Convince the scientist that the primary mission of shuttle program is science and they will not be considered in a secondary role as in the past (lack of trust based on past experience) by clearly depicting the decision process and involvement of scientist.

- b. Set up of an organization structure and functional interfaces that clearly demonstrates appropriate involvement of scientists in the decision process so as to guarantee priority for accomplishment of scientific objectives within available resources.
- c. Change the title from "Principal Investigator" to "Mission Integration Scientist."
- d. Provide an inducement by giving those scientists who build the instrument first option for use of the facility as a reward.

Condition IV: Personnel in the field centers are not informed of overall shuttle objectives, plans, progress, and mission assignments. Lack of knowledge of who is working in same or related mission areas in other centers.

- Results:
- a. Duplication of same efforts. i.e. and definition studies among centers.
 - b. Lack of sharing of information and experience gained on common problems among mission areas. i.e. cryogenic cooling problem.
 - c. Increasing of competition beyond contributory levels among Centers.

- Action:
- a. Clarify mission project assignments among field centers.
 - b. Communicate to all NASA personnel those assignments.
 - c. Establish more opportunity for face to face communication among all who are working on common mission or related projects and quarterly reviews of all projects.

Condition V: There is a great deal of contention among the scientists on one hand and the engineers and program managers on the other one who should have the ultimate authority during instrumentation and facilities during the Definition, Design/ Fabrication phases. Scientists point to the apollo program as a way not to go and Program Managers and Engineers point

to Skylab program as a way not to go.

- Results:
- a. Lack of willingness on the part of either scientist or engineer to include the other in their aspects of the preliminary analysis or Definition projects.
 - b. Lack of willingness on the part of either the scientist or engineer to consider alternative modes of operations for shuttle.
 - c. Inadequate use of experience and knowledge by scientists and engineers from the other during the preliminary analysis and Definition phases.
 - d. Lack of integrative planning process in which science, engineering, and operations requirements are considered currently to the optimum plan within technology, cost and time considerations.

- Action:
- a. Develop a program management model that delineates functional accountability and functional inter-relationships of the scientists, engineers, program managers and contractor which provides for appropriate inputs of each during the planning, fabrication, and operational cycle.
 - b. Establish planning procedures which require scientist, engineer, and project managers direct interface and contact during the development of the Program Plan. (Phase A, B, C)

4.2 Program Status and Management Issues.

The following is an analysis of the data collected at the Field Centers and Headquarters:

SUMMARY

The shuttle program requires re-thinking and adjustment of operations and relationships within Headquarters, the Field

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Centers and between and among Headquarters and the Field Centers. The methods of operations and concepts of management established for Apollo and other recent programs.i.e. Skylab can not be directly applied to the shuttle program. It not only requires adjustment in organization structure, functional interfaces and decision processes, but also, and perhaps most importantly, the re-orientation of OSS and OSMF personnel as well as those in the Scientific Community to the different requirements differing modes of shuttle operations. the apparent major re-orientation for those of the Scientific Community and within NASA is the change from the management concept for the Principal investigation to that of a facilities concept, although there has been some similar experience of using ground facilities in the facilities concept mode. It is not wide spread nor has the implications been applied to the shuttle sortie mode. It is our belief that neither the Scientific Community nor NASA has yet come to grips with this fundamental operational concept change. The results is a business as usual which is beginning to prove less than adequate for the accomplishment of the Physics and Astronomy (and all scientific missions) Pay Load Program.

This problem area should be addressed and studied as soon as possible so that the appropriate organizational, functional, and functional relationships adjustments required within NASA can be made to enable an effective accomplishment of shuttle scientific missions program. Delays in addressing and resolving these areas of accountability will result in increased cost and missing time target established and committed to by NASA. There are many unanswered problems involved in the shuttle program and the current accountability among NASA elements are not clearly defined and therefore inadequate for assuring effective problem resolution.

A second and perhaps as important management issue is the look of an overall Program Plan for Astronomy and Physics shuttle pay load program. The need for adaptive planning for this program that involves a variety of organizations, individuals, developmental tasks over an initial phase of 10 years is quite evident. But, without initial overall program plan, Headquarters does not have the criteria or basis for making the priority and trade off decisions required now and the Centers lack the general guidance for directing their resources and efforts. The less than satisfactory pace of center efforts attest and will continue until the overall Program Plan is developed and approved by NASA top management.

5. PHYSICS AND ASTRONOMY SHUTTLE SORTIE OBJECTIVES

5.1 ATMOSPHERIC SCIENCES FACILITY

The Earth Atmospheric Science Experiments are designed to increase man's understanding of the mechanisms controlling the near-space environment of the earth. Measurements of airglow and auroral emissions will be used to determine the spatial and temporal variations of both the temperature and density of atmospheric constituents. Investigations which will aid in the understanding of planetary and cometary phenomena will also be performed. Particular emphasis will be placed on distribution of molecular oxygen and the inferred production rate of atomic oxygen. Those minor atmospheric constituents important in the photochemistry of the atmosphere, such as ozone, atomic hydrogen, carbon dioxide and the nitrogen oxides, will also be studied.

Airglow Measurements The airglow measurements will satisfy three basic objectives. The first is the study of the tropical airglow emissions; the survey of airglow emissions; and third, a general investigation of several emission lines between 2500 and 10,000Å.

The Tropical Oxygen Emissions (TROPLES) measurements will be made of the 1356Å, 1304Å, 4368Å and 774Å lines due to oxygen (OI). The reaction mechanisms producing these emissions are uncertain however, continuum emission between 900Å and 910Å is expected theoretically. Measurement of this continuum will reveal whether radiative recombination is the dominant process.

Satellite measurements are essential for studies of this phenomenon since it is thus far impossible to predict with certainty the appearance of tropical UV airglow. Continuous monitoring of the 900-910Å

enhancements of twilight airglow emissions and of the electron temperature. Such enhancements have been measured in the 6300\AA and 1304\AA , OI lines. However, the interpretation of conjugate effects in the 6300\AA , OI line is complicated by the existence of the strong airglow line at night. Observations of the conjugate photoelectron phenomena in the XUV are not affected by any nighttime airglow background. The Shuttle Sortie is particularly well suited for such observations since it is above the peak of the atomic oxygen distribution at 120 km where the conjugate electron excitation will occur.

The production rate of O in the D-region is of special interest to atmospheric scientists. These rates will be established by determining the intensity of sunlight from 1000\AA to 1100\AA as a function of altitude. The production rate of O from O_2 $\Delta\delta$, the only important source of atomic oxygen at these altitudes, can be calculated.

In addition to the production of O from O_2 , the temperature and vertical distribution of O_2 will be investigated by measuring the attenuation of solar radiation in the region from 1450\AA to 1950\AA . Ozone and the nitrogen oxides will be measured by observations of the twilight airglow.

Aurora Measurements

Model auroral calculations begin with a measured or inferred incident flux of energetic particles and end up with excitation of spectroscopic emission features, ion composition, electron and ion heating, and heating of the neutral gas. Such calculations have not been able to account for all of the energy deposited by the primary bombarding flux. Part of the remainder may go into dissociative ionization - excitations

region, and the 1304A, 1356A, 4368A and 7774A lines from the Shuttle will provide a continuous survey of the electron density near the F region peak if the recombination mechanism is confirmed. This form of remote sensing is not limited to the nadir or zenith nor to only one side of the F peak, as is the case with the bottomside or topside sounders.

The strongest emissions are in the tropical regions, but with improvements in sensitivity (possibly using Hadamard coded multiple slits or a grille spectrometer) monitoring at higher latitudes can be performed.

A survey of the XUV, Far UV, and the Near IR will provide significant new data since existing data on the day and night airglow in these regions consists of only a small number of measurements made with broadband photometers. Moderate or high wavelength resolution, spatial, and temporal studies have yet to be performed.

Flexible instrumentation will be provided so that optimum data gathering can be achieved. Variable fields of view and spectral resolution will allow the observer to operate the equipment in a variety of modes from the coarse survey mode to a mode optimized to detect small differentials.

The TROPLES measurements will contribute to a quantitative explanation of the nighttime ionosphere.

In conjunction with the general airglow survey, a search for locally enhanced regions resulting from specific sources of excitation will be conducted. These sources are of particular interest since fast photoelectrons created at high altitudes in the sunlit atmosphere can travel under suitable conditions, to the dark, atmosphere; subsequently, they cause

where the products are in excited states. The lines of interest are those of NI, NII, OI, and OII. While the production rate of excited states may not be large, the energy associated with each event is appreciable and may explain the auroral energy balance problem. The magnitude of the excitation cross sections are uncertain.

Such measurements are difficult to perform in the laboratory, and space experiments may be able to provide useful cross sections for specific transitions of importance.

Although only a few emission lines are required, a general survey from 300 to 1250A is needed because of the uncertainty as to the produced spectrum and in order to deduce the character of the bombarding flux by comparison with well known emission features.

For the aurora measurements of the entire far ultraviolet band pass (1250-3500A) contain various emissions of interest; for example, the 100 - 2600A N₂ Lyman - Birge - Hopfield series. The principal molecular emitter in the aurora is nitrogen.

A complete set of measurements at 10A resolution is needed in order to correlate the far ultraviolet features with the other spectral regions.

Minor Constituents and Pollutants Measurements

The determination and understanding of the minor constituents and their photochemistry are crucial to understanding the earth-sun radiant energy balance, and the effects on the environment on earth which are altered by gaseous pollutants.

When the ever-increasing problems of atmospheric pollution are solved, a global survey to quantitatively determine the distribution and dynamics of the natural minor constituents and pollutants will be needed.

Measurements of minor atmospheric constituents can be made from space by analysis of spectra obtained in absorption, reflection and emission. Absorption measurements, using the sun as a source have been used to determine twilight diversities of ozone nitrogen dioxide, carbon dioxide, and molecular oxygen (a minor constituent above about 150km). Diffuse reflection yields information on ozone and, if polarization is determined, aerosol and dust distributions. Emissions, measured at twilight and at night are specific to molecular nitrogen, nitric oxide, the hydroxyl radical, and atomic oxygen.

Planetary Atmospheric Sciences

Measurements of the atmospheres of the planets are important to the objectives of the Space Shuttle Aeronomy Program because they provide unique comparison data crucial for the resolution of ambiguities in earth data and because they are of interest in their own right in the study of the origin and evolution of the solar system. For example, the relative importance of the various hydrogenic compounds in the earth's atmosphere in producing atomic hydrogen is unknown. The recent observation of the Martian exosphere, produced solely by the dissociation of water vapor by sunlight, may help us to resolve the problem on earth. Likewise, the measurement of the escape rate of the Martian exosphere shows us that Mars is presently outgassing water vapor.

The planetary atmospheres will be measured using the same modes and equipment in the aeronomy facility as is used for terrestrial measurements. In this way systematic errors due to unsuspected differential instrumental effects can be eliminated.

Solar Measurements

The space and time variation of the earth's exchange of solar radiation with the

atmosphere and atmospheric radiation with space is the fundamental forcing function that drives the overall motion of the atmosphere and the oceans.

Although a great deal of information has been gained through the use of unmanned satellites, better precision and absolute accuracy of the energy flux measurements is still needed to meet present meteorological requirements. For example, the longterm (climatological) problem of earth warming or cooling due to inadvertent or natural modification of our environment has not yet been solved. Highly accurate simultaneous measurements of the solar constant, the reflected solar radiation, and the terrestrial emitted infrared radiation are needed.

One of the fundamental physical parameters that determine the spectrum of the dayglow is the spectral distribution of the solar radiation that falls on the atmosphere.

Measurements of the absolute spectral distribution of the solar radiation falling on the earth's atmosphere have been made on a few occasions. The temporal variations of this radiation are, as yet, largely unknown. Without this knowledge, the subsequent analyses of dayglow processes are subject to considerable uncertainty.

Therefore, measurements from 1100\AA to 30μ of the solar flux will be made in order to provide the required flux data for dayglow analyses.

The capability for simultaneous measurements of the direct solar radiation, the reflected solar radiation and the thermal radiation, will be available.

5.2 COMETS AND ASTEROIDS

Near Earth measurements of comets have been attempted with aircraft and sounding rockets but the most revealing measurements can be attributed to the OGO and OAO UV measurements of comets Tago-Sato-Kosaka, Bennett, and Encke. As predicted there is a large halo of hydrogen Lyman α emission, and the OH emission is also strong.

Very little significant data exists on the physical properties of the asteroids mainly because they are relatively small objects when seen from Earth and in some cases they pass rather quickly, hardly allowing time for orbital data to be obtained so that their next appearance can be predicted.

The following sections describe the objectives for Cometary physics, general cometary science, comet tails, and asteroids.

Cometary Physics: Several Shuttle experiments have been selected which will increase our understanding of cometary physics and certain of the aspects of the optical contamination problem. These experiments are laboratory investigations to be performed on board the Shuttle and would take advantage of the scientist/astronaut.

Cometary Release of NH_3 and ICN

Chemical releases of NH_3 (ammonia) and iodine cyanide are proposed to study the fluorescence of the evolved radicals NH_2 and CN which occur in cometary emissions. Relatively small amounts (1 to 3 moles) will be released from appropriate canisters engineered to minimize the formation of particles whose

Mie scattering would mask the fluorescence. A rotating multiple spectral pass-band detector would measure the radiation at various vibration transitions. From this measurement a comparability of photolysis as the causative mechanism could be completed. Such an experiment would also help to evaluate the fluorescent effect of contaminants on spacecraft sensors.

Measurement of Volume and Size Concentration of Particles Surrounding the Shuttle

A novel technique exists for measuring the distribution (integrated scattering) of particles per unit volume at different distances from the Shuttle in contrast to the proposed measurements of the integrated mass per cm^2 extending from the spacecraft to infinity. Additionally, some sizing information would be available. The concept involves the use of two mirrors whose intersecting field-of-view defines a volume. The sun is reflected from the first mirror after passing through a light modulator. There are two detectors which measure only the AC component of the scattered light. One detector measures the scattered radiation from the second mirror while a second detector located mid-way between the two mirrors measures the scattered radiation at a different angle. In this way, depending upon the scattering phase function, some indication of size is obtained as well as scatter-

ing mass as a function of distance.

A Monopole Mass Spectrometer Experiment

A monopole mass spectrometer designed to possess a novel sweeping mode can sample molecules up to mass 400 and can be adapted for larger masses. Because the presence of heavy molecular weight polymers, due to nucleation of such species as H_2O and breakup of polymers on Shuttle surfaces, is indicated, an instrument of this capability would be of value in measuring their concentration in the Shuttle environment as well as that of lower molecular weight species.

Selection of Spectroscopic Chemical Release Experiments for Cometary Research

It is possible to simulate the spectroscopic character of cometary emissions by the release of a gas which produces desired cometary radicals at an optimum rate. Such an experiment can then be used to study the behavior of the radicals created. For many molecules the photodissociation times are not known but a limited number of measurements have been made. Such time constants for photolysis it is considered may possibly be studied more accurately from a spaceship since it automatically includes the complex intensity distribution of the solar spectrum. For example, the fluorescence spectrum may be studied with the effect of the Fraunhofer lines on the profiles integrated into the total fluorescence picture in contrast to

the laboratory simulation of fluorescence. The results of these space experiments may then be compared with existing cometary spectra of a similar nature.

A basic problem with such fluorescence experiments is that they are two-step processes in which first a dissociation must occur prior to the fluorescence. Consequently this relatively slow dissociation of the parent molecule in conjunction with the limited amount that can be carried in the Shuttle and rapid diffusion rates implies a relatively weak fluorescence. Care must be taken to minimize the background scattering. Two possibilities which will be discussed below are those for studying NH_2 and CN fluorescence which seem to have optimum possibilities.

Nucleus Investigations

It is important to learn the nature of the nucleus of a comet, relating to its origin and evolution, by direct study of the nucleus. The major objective is to identify the existence of a nucleus and to determine whether or not it is a single coherent body. This may be achieved by resolving a central body and determining its dimensions and shape with an accuracy of $\pm 10\%$. The same instrument which detects the nucleus (TV or photometer with a slit) can be used to measure its albedo.

General Cometary Science Investigations: To support the general field of Cometary Science, studies of the optical thickness of the coma in different lights should be encouraged. High resolution spectroscopy has already led to many important new results; however, high resolution spectra have been obtained for a few comets only, and for a limited wavelength range. Observations of this type should be encouraged and extended to more comets. Furthermore, monochromatic polarization observations in the continuum and in selected lines could bring much new information and the monochromatic isophotes of the coma should be studied in the continuum and in selected lines or bands.

Comet Tails Investigations: Cometary tails are the least known parts of comets and thus any data that can be obtained from the ground or in the laboratory is potentially valuable. In particular, not enough spectral coverage (in IR and UV) has been obtained for cometary tails. Observations from the Shuttle in the UV to search for H, OH⁺ and other species is extremely important. These observations should be performed for all comets with bright enough tails but especially for a candidate target comet, to identify tail species in advance of the mission.

Theoretical studies are needed to define what would happen to a ball of ice in a super Alfvénic plasma, and how it would interact with the plasma. Studies of Mie scattering should be instigated to determine the theoretical polarization and brightness of cometary tails for comparison with

actual data. Theoretical studies of OH^+ (f-values) should be correlated with data on the electronic bands near 4000 Å.

Visual photographs of the cometary coma and tail, with a time resolution fast enough to track the motion of any knots or streamers should be obtained. Also cometary spectra should be obtained from the ground and earth orbit to detect species in the tail. Related solar wind measurements will be advantageous.

Asteroid Investigations: Generally speaking, detailed investigations of the asteroids will be of the same nature as those for comets. There are at least two additional aspects of scientific importance associated with the asteroid belt. The mass distribution, which is not known, may present a serious collision hazard for space missions to the outer solar system. Data revealing the origin of the asteroids and their relationship with the planets will provide supporting evidence for the origin of the whole solar system.

Mass Distribution in the Asteroid Belt

The mass distribution of the asteroids will provide data on the collision history of the belt but of equal immediate interest in the collision probability for a spacecraft either passing through the belt or even sent specifically to take measurements there. Particle mass and energy measurements will not be too difficult to obtain for micrometeoroids but will be subject to chance and hazard for larger masses. The results of such a series

of experiments from the Shuttle could be used to formulate the precautions necessary before direct penetration through the entire belt should be undertaken.

Origin of Asteroids

The asteroids may well be considered as secondary targets compared to the major planets but they have one important advantage in the information they can give on the internal structure of planet type material. The fragmentation of asteroids reveals cross sections of the structure of the original larger bodies, and although subject to aging by micrometeoroid collisions and sputtering, it may be possible eventually to theoretically reconstruct the originals. Further, since the bodies which are suspected of being original planetary condensations are much smaller than the planets, they may not have aged in the same way. The lower internal pressures and temperatures may well give information pre-dating that available from the planets. A factor of considerable significance to our knowledge of the solar system would be to derive data which would identify meteorites which were previously asteroids.

5.3 HIGH ENERGY ASTRONOMY

The discovery and study of objects which have almost all of their energy output in the X-ray range have already made substantial contributions to our understanding of high energy processes. Temporal variations, in particular, have been a rich source of the identification of the energy sources required to drive the high energy processes involved in X and gamma ray production.

Gaps still remain in the understanding of crucial aspects in the evolution of high energy photon emitters. The evolution of supernova remnants, the details of the output mechanisms of X and gamma rays sources, and the energy input parameters are problems for the high energy astronomy shuttle sortie. The need exists for detailed study of the diffuse radiation, both galactic and intergalactic to determine the distribution, dynamics and history of the nuclear and electron components of cosmic rays.

The specific objectives for the X and gamma ray astronomy are best presented in four energy intervals. The divisions by energy are based upon the physical processes responsible for radiation at these wavelengths and on the instrumentation required to study the radiation.

X-Ray Astronomy (.02-2 KeV)

The X-ray astronomy, in the .02-2 KeV range will perform detailed studies of the energy emission spectra and attempt correlation with radio and optical emissions. The absorption feature in the spectra will be used for interstellar and intergalactic media investigations. A variety of polarization and spatical variation over extended objects will be conducted. In addition temporal studies on time scales greater than on millisecond,

both periodic and aperiodic and surveys for weaker sources not yet detected will be conducted.

X-RAY ASTRONOMY (2-50 KeV): In the 2-50KeV range, a detailed study will be performed of spectral features with resolution sufficient to resolve heavy element K emission and sharp continuum features which could be signatures of the emission processes. Temporal analyses on time scales from less than a millisecond to a year will be performed to identify the energy input processes. Spectral correlation with lower energy X-ray absorption measurements will be performed to identify cosmic ray induced emissions in the interstellar medium. In addition polarization studies and correlation of temporal variations with measurements in other regions will be performed.

Low Energy Gamma Ray Astronomy(0.05 to 10 MeV) Specific sources of gamma ray line emissions will be studied which may have been discovered in the sky survey performed by HEAO. The location, extent, intensity, degree of polarization and detailed spectrum of X-ray and gamma ray sources will be determined in the .05 to 10 MeV energy interval. New sources will also be sought in this region. The time variations in the intensity and spectral details of discrete X-ray and gamma ray sources will be observed. Also, the origin isotropy and spectral details of the diffuse X-ray and gamma ray background will be studied.

High Energy Gamma Ray Astronomy (10MeV) In the region above 10 MeV a full sky survey, at high sensitivity, for discrete sources and measurements of their flux, energy spectrum, and location will be performed. The physical characteristics of specific gamma ray sources will be determined by detailed

study with fine time, energy, and spatial resolution. The galactic plane structure will be studied with high sensitivity, good energy resolution, and fine angular resolution to understand in depth the distribution of cosmic rays and this role in the dynamics of the galaxy. In addition, measurements will be made of the intensity and energy spectrum of the diffused radiation from regions other than the galactic plane and searches conducted for short, intense bursts of gamma rays.

5.4 HIGH ENERGY COSMIC RAY LABORATORY

The study of high energy cosmic radiation affords a powerful means of probing the universe and aiding in our understanding of various astrophysical phenomena. Measurements of the energy spectrum, nuclear composition, charge spectrum and directionality of high-energy cosmic rays can yield valuable insight into the age and origin of the universe and of the elements.

Composition of galactic cosmic rays: The charge composition of galactic cosmic rays, their energy spectra and their directional properties contain information about their propagation in the interstellar medium. Changes in the shape of the energy spectra or charge composition at high energies would have important astrophysical consequences relating to their acceleration and containment in the galaxy. It is planned to determine accurately from direct measurements the flux of cosmic-ray nuclei and their charge spectrum from 10^{12} eV to about 10^{16} eV.

Electron and Positron Spectrum: The shape of the high energy spectrum (10^{10} eV) should provide important clues concerning the age of electrons, the source spectrum, the acceleration mechanism, the storage times and the distribution of cosmic-ray electrons in the galaxy. High energy electrons also provide information on the interstellar energy density of photons and magnetic field strengths. The electron-positron ratio, as a function of energy, is important for understanding source and propagation mechanisms.

Isotopic Composition of Cosmic Rays: The isotopic composition of the secondary cosmic rays is important in determining cosmic-ray age and production mechanisms as well as providing a measure of the source function and the distribution of interstellar matter. The isotopic composition of primary cosmic rays carries information about the thermonuclear element building.

Anti-nuclei Search: A small number of anti-protons are expected to be created by proton-proton collisions in interstellar space. They can be interpreted in terms of cosmic-ray lifetimes and the galactic matter density. The observation of an antinucleus would imply the existence of antimatter stars, and would have profound significance regarding the nature of the galaxy and the universe.

Anisotropies: It is planned to search for anisotropies in both the nuclear and electron components of high energy cosmic rays. At energies $\geq 10^{15}$ eV, where the cyclotron radii become comparable to the dimensions of the galactic structure, a measurable cosmic ray anisotropy should be evident if the sources are located in the galactic disc. Anisotropies in high energy electrons would tell us much about the location of nearby sources and interstellar acceleration.

Flux and Charge Spectrum for $Z=30$ to $Z \geq 100$: Investigations with good statistical accuracy of the flux and charge spectrum of the very highly charged cosmic rays, $Z=30$ to $Z \geq 100$ are ideally suited for Shuttle Sortie missions. These ex-

periments are very sensitive to the presence of the Earth's atmosphere as well as requiring enormous collecting areas. Good experimental data will be important in understanding the synthesis of elements and the source and acceleration mechanisms. The abundance ratios of radioactive transuranic nuclei relative to the stable isotopes should provide a direct measure of the age of cosmic rays. A search will be made for elements heavier than those known on earth.

Continuing Investigations and Searches: There are a wide variety of continuing investigations and searches to be conducted. There is interest in a search for high-energy, neutrally-charged components of the cosmic radiation because it is understood these particles should not be present with observable fluxes. If found, their discovery would be of major importance. Also it is possible that the failure to observe quarks and magnetic monopoles in the laboratory can be attributed to the nonavailability of sources of artificially accelerated particles of sufficient energy. The conduct of investigations of high-energy interactions, such as measuring high-energy cross sections, multiplicities, and elasticities would be limited to those experiments which are not feasible with ground-based facilities.

5.5 INFRARED ASTRONOMY

Astronomical observations in the infrared portion of the electromagnetic spectrum are severely hampered by the earth's atmosphere. Absorption due to saturated molecular lines begins at roughly 1 micron, extends to 1 or 2 millimeters, and is nearly complete except for a limited number of spectral "windows." Even at aircraft and balloon altitudes where the transmission is greatly increased, observations suffer from atmospheric emission. Nonetheless, a significant number of important, sometimes startling, observations have been made in the infrared, indicating that studies in this region of the spectrum will contribute greatly to the present body of astronomical knowledge and our understanding of astrophysical phenomena.

A list of objectives is given below which indicates the potential contribution of infrared astronomy to our knowledge of the universe. In addition to those described infrared observations are a vital portion of the solar physics, planetary atmospheres, comets and asteroids, zodiacal light and gegenschein activities planned for the Shuttle Sortie.

Background Radiation: In order to clarify the true nature of the universal microwave background radiation (thermal vs non-thermal), a set of accurate observations must be made in the range roughly 500μ - 1 mm, well beyond the expected peak of a 2.7°K blackbody. The large and small scale anisotropies should be investigated since observations from space in this spectral region are capable of a good deal higher sensitivity

than can be gotten in the microwave region.

Extra Galactic Sources: Infrared galaxies, Seyfert galaxies, and quasars exhibit a high flux of radiation at 10 microns, which appears to increase sharply toward the longer wavelengths which are not visible from the ground. Most of the luminosity of these objects may well be in the infrared indicating that the physical processes going on are even more violent than had been thought. Studies of these galaxies throughout the infrared are necessary to uncover the nature of the violent activity. The variability of these objects in the infrared is still unresolved and is of extreme importance.

Galactic Non-Thermal Objects: There is as yet no observational knowledge of non-thermal infrared radiation from galactic objects, such as is available in the radio region (e.g. for supernovae). In particular, the galactic center, which is a strong radio and infrared source is known to have a complex structure at 10 microns and is observed to emit a non-thermal radio spectrum. Relatively high spatial resolution studies at several different wavelengths are needed in the far infrared (40-200 microns) to understand the relationship between the infrared and radio objects.

Interstellar Dust and Circumstellar Dust Shells: The thermal radiation from interstellar dust occurs largely in the region of the spectrum ranging from 40 to 400 microns. Compact as well as very extended emitting regions have been

observed at 100 microns. These objects appear to be dust clouds heated by nearby hot stars to temperatures in the neighborhood of 50°K. These regions are likely candidates for the initial steps of star formation through gravitational collapse and play an important role in the formation of interstellar molecules. A number of categories of stars exhibit an "infrared excess" at 10 microns. This appears to be due to circumstellar dust shells formed from material condensed in the stellar envelope. This material radiates thermally, primarily in the 5 to 50 micron region. Emission peaks, most probably due to silicates, have been identified in the 10 to 20 micron windows. Studies at moderate, spectral resolution from above the earth's atmosphere are required in the 5 to 50 micron region to determine the composition of the dust, the mechanisms for its manufacture, and the way it is eventually dispersed into interstellar space.

HI and HII Regions and Planetary Nebulae:

Infrared line emission serves as an important cooling mechanism in the energy balance of both the general interstellar medium (HI regions) and diffuse and Planetary nebulae (HII regions). Present theoretical models utilize forbidden line emission processes that radiate in the 10 to 100 micron region, hence observations of this line emission are required to help verify the credibility of such models. Studies of the forbidden transitions are particularly powerful in determining physical parameters such as temperature,

density, abundances, etc. Ground-based observations are limited to the few very bright sources. High resolution studies of the small-scale spatial structure that is known to exist, but poorly understood, in HII regions will be conducted.

General Infrared Survey: Approximately 100 objects have been discovered by stratospheric observations at 100 microns and covering a relatively small fraction of the sky. This list of objects has practically no overlap with the Cal Tech 2 micron catalog. The infrared sky is totally different from the optical and near infrared sky. An infrared survey is required in the spectral range 10 microns to 300 microns.

Stellar Abundance and Structures: Late-type stars and variables (spectral types K4 and later) have temperatures less than 4000°K . Under these conditions the light elements H, C, N, D, Si, etc., have strong tendencies to form diatomic molecules such as CO, DH, NH, SiO, etc. The ability to observe, at one time, all the vibration-rotation bands of these molecules can provide an enormous amount of information on the evolutionary state, isotopic ratios, and the thermal and mechanical structure of the atmospheres of such objects. Unfortunately, because the molecules are light, the bands cover very wide ranges of the spectrum, most of which cannot be observed from earth. The ability to observe the Q and R branches from the Space Shuttle would allow definitive values to be placed on

the conditions of non-LTE in the stellar atmosphere, which, in turn, would permit much better explanations for certain anomalous isotope ratios in these stars. In turn, these isotope ratios can provide a direct measure of the evolutionary state of the star by means of the known properties of the CNO bicycle.

Since early type stars are quite faint, they must be observed outside of the atmosphere. Observation of the near infrared lines of hydrogen and helium will serve to show non-LTE effects when compared with observations of the visible lines. These stars can also be used as light sources for measuring extinction and the intensities of the interstellar fine structure lines.

Protostars and Planetary System Formation: Some systems of stellar-like objects and dust which have been seen to undergo structural changes over short time scales may be protostars, perhaps with attendant planetary systems, in the process of formation. Such objects would almost certainly emit the bulk of their radiation in the infrared. Study of these objects requires the high spatial resolution throughout the far infrared which is obtainable by a large (3 meter) telescope.

5.6 : MAGNETOSPHERICS

Plasmas, at various concentrations, represent a major constituent of the Universe -- an understanding of the physics of plasmas is, therefore, an important objective, and the Shuttle is capable of providing a laboratory platform for the performance of experiments essentially free from wall effects. This is particularly important for the non-linear effects which cannot be easily scaled. Examples are the wake effects produced by a body moving in a plasma, the interactions of an antenna at high power levels with a magnetoplasma, and the plasma memory effects. Use of the Shuttle as a diagnostic platform also falls under this heading: it is known that powerful ground-based transmitters can significantly perturb the ionosphere, but the detailed interactions are not understood, and overflights of a well-equipped Shuttle laboratory promise to provide a powerful diagnostic tool for such investigations.

Plasma Physics Objectives: The plasma measurements will investigate the plasma wake around a large body in space, the interaction between particles and

- radio waves,
- locally generated plasmas, and
- chemicals,

the behavior of plasmas without walls and their response to radio pulses and plasma resonances, including the basic physics related to plasma memory effects observed in ground-based laboratories.

The plasma wake determinations will include

measurements of the local electron density and temperature perturbations, as well as the ionic constituents in the vehicle wake using probes and spectrometers. The spectral properties of electrostatic plasma waves (turbulence) associated with the wake structure should also be made. Perturbations induced by vehicle motion and their relation to the natural ionospheric phenomenon called "Spread-F" are of particular interest.

A wide variety of experiments are included in the general area of particle interactions. These experiments emphasize the interactions of certain plasma particles with locally generated waves with wave modes extending over a large frequency range. The interactions of interest generally occur near the Space Shuttle or on field lines passing through the spacecraft. Chemical releases are also planned for international ground based observations by a large number of scientists throughout the world.

The conduct of plasma physics experiments on board the Space Shuttle presents the physicist with a unique opportunity to study the behavior of plasmas and their response to radio waves without the usual laboratory constraint of walls. This will permit extensive investigations into the subjects of plasma resonance, plasma memory effects, and the general properties of plasmas - the major constituent of the universe.

Environmental Perturbation Objectives: The specific objective of the environmental perturbation measurements is to produce diagnostic perturbations in the

magnetosphere or ionosphere in order to identify the underlying mechanisms which govern the behavior of the magnetosphere. To this end, many of the same experiments as the plasma physics are planned. The major characteristics of the perturbation experiments is the use of Space Shuttle as a means of delivering disturbances in the magnetosphere. These disturbances include the use of the following:

- release of chemicals,
- large amounts of radio energy,
- locally generated plasmas,
- electron guns, and
- ion guns.

It is planned that a coordinated plan for these disturbances will involve the extensive use of ground observers and ground based instruments to observe the effects of the disturbance.

Measurements would also be made by the Shuttle of ionospheric perturbations produced by ground-based transmitters. Other perturbation experiments would include the in situ study of parametric instabilities excited at plasma resonance, the release of barium canisters in the auroral zone to possibly trigger an auroral substorm, and the injection of electrons to produce artificial Van Allen zones and studies then made of drift, diffusion and loss. In addition, it has been suggested that a properly modulated space radio transmitter can reduce the trapped particle population.

Specific Areas of Investigation: Magnetospheric physics experiments will be performed in the following areas:

- Energetic Particle and Tracer Experiments are designed to shed light on the configuration of the geomagnetic field and the processes that provide stable or quasi-stable trapping of energetic particles.
- Beam-Plasma Experiments are emphasizing interactions of beams (generated by electron or ion guns on the Shuttle) with the ambient plasma. This category includes artificial auroras.
- Wave-Particle Interaction Experiments will emphasize the interactions of certain plasma particles with locally generated waves. These experiments utilize wave modes extending over a large frequency range (fractions of Hz to many MHz) and the interactions of interest generally take place near the Shuttle or on field lines passing through the spacecraft.
- Wave Characteristics Experiments will emphasize the study of wave propagation and damping characteristics, plasma instabilities, and wave-wave interactions.
- Wake and Sheath Experiments are designed to study the wake or sheath around orbital bodies.
- Magnetospheric Modification Experiments are designed to produce large scale perturbations in the magnetosphere or ionosphere and to identify the underlying mechanisms.
- Plasma Physics in Space Experiments are essentially those laboratory-type experiments that can be performed better in space to take advantage of large volumes, high vacuum con-

ditions and/or weightlessness. Also experiments which use the ambient plasma present in the upper ionosphere.

- Propulsion and Devices Experiments ultimately have applied goals. The propulsion studies utilize ion thrusters or ($\underline{v} \times \underline{B}$) electric fields. The other general area here involves development of new diagnostics and resolution of outstanding problems connected with use of standard diagnostic techniques on unmanned rockets and satellites.

5.7 SOLAR PHYSICS

The object of the Shuttle Sortie Solar Physics program is to conduct coordinated problem-oriented observing program of typical solar physics investigations on active regions, flares, prominences and filaments, synoptic observations of the Corona, quiet sun atmosphere, supergranulation, coronal transients, solar wind and chromospheric oscillations.

These are oriented to obtaining solution to the following questions:

How energy and material is transported from the core of the sun to the photosphere, through a temperature minimum to create and sustain a hotter chromosphere and still hotter corona.

How magnetism originates, evolves and is distributed throughout the sun.

What physical processes are responsible for the 11-year cycle of solar activity which result in the formation of sunspots and prominences and produce the rapid conversion of stored energy into the kinetic energy of relativistic particles associated with solar flares.

Whether solar abundances differ from layer to layer in the sun.

The mechanism of solar flares and the transfer of flare energy to the earth.

To answer the above questions, specific measurements follow, according to the portion of the electromagnetic spectrum involved.

Optical, UV, XUV: Simultaneous observations at

selected wavelengths within this spectral range are required. From this common object viewing it may be possible to determine if the x-rays emitted from the same spatial region (to within 0.1 arc second or better) as ultraviolet flux, exhibiting certain spectral features, and/or are magnetic fields also to be associated with this point in space or in the surrounding space.

The location of significant objects requires that techniques must be developed to predetermine and/or quickly determine the location of solar features of interest. This is particularly important when the solar feature has a short lifetime. How does one quickly locate a very small object (~ 0.1 arc second), which has a short lifetime or significant decay history, on the solar disc before the object disappears and/or the object has proceeded significantly through its rise of decay lifetime?

X-Ray and Gamma Ray, Neutrons: The objective is to acquire a comprehensive set of measurements on the characteristics of X- and gamma-ray and neutron emission from the flaring and non-flaring sun in order to obtain insight into the triggering mechanism of a solar flare, the total energy content of a flare (in conjunction with other measurements), and into the acceleration, containment and release of charged particles in the sun and during the flare. The characteristics in the photon spectral range of .001 to 10 MeV that must be measured to achieve this objective are:

spectral energy distribution in continuum
and line radiation;

temporal history of the emission with a time resolution of better than 1 (one) second;

polarization of the emission;

location of the emission in the solar atmosphere as a function of time and energy (this may be possible only for limb-flares).

The needed characteristics for neutrons are flux, spectrum, and time history.

These measurements will be of greater significance when compared with simultaneous radio spectral and spatial measurements and solar particle measurements. It is anticipated that most of the radio measurements could be made from the ground, others from satellites which are in lunar or highly eccentric orbit.

Infrared: Solar physics can profit from infrared observations in at least four areas:

- Infrared molecular lines can be used, for example, for abundance determination
- Infrared forbidden coronal emission lines can be used for the interpretation of XUV spectrum in terms of physical conditions in the corona
- Continuous emission such as in rare white light flares could be more frequent in the infrared and indicate a synchrotron mechanism
- The far infrared continuum is important for the study of the chromospheric temperature minimum.

Instrumentation for these purposes is likely to be used intermittently for solar physics and be identical in concept to IR Astronomy instrumenta-

tion. The requirements of early IR solar physics are likely to be served by the occasional use of IR Astronomy Facilities provided the option to look at the sun is maintained in IR Astronomy instrument development.

The spectral coverage of high sensitivity instrumentation is generally determined by detector selection for a given spectral region and/or limited logistic support for cooled detectors. Broad spectral coverage is accomplished by selecting less sensitive detectors such as bolometers or thermally sensitive pneumatic sensors (such as the Golay Cells). Temporal response characteristics of infrared detectors complicates the techniques of instrumental design in obtaining high sensitivity as well as broad spectral coverage. The Shuttle Sortie and/or resupply operational capability may open the way to perform observations hitherto rejected because of logistic limitations-particularly in the selection of cooled detectors.

Besides applying the techniques of double dispersion spectroscopy and/or multiple beam (FABRY-PEROT) interferometry to obtain high spectral resolution, the techniques of Fourier and Hadamard scanning instrumentation may be applicable for coronal emission lines.

5.8 ULTRAVIOLET/VISIBLE ASTRONOMY

The Shuttle Sortie Ultraviolet/Visible Astronomy Observatory is suited for limited purpose programs, specialized programs, exploratory programs, as well as correlation and validation programs. The following sections describe typical objectives for investigations included in the first three categories.

UV Broad Band Survey/Spectral Survey: The objectives of these programs are to secure a multiband ultraviolet photographic atlas of the sky (equivalent in quality to the Palomar Survey) and a low resolution spectral survey equivalent in the ultraviolet to the standard Henry Draper catalogue. These are well defined programs which require only limited observing time. The shuttle sortie mode permits the use of photographic recording and storage of the data, an overriding consideration for achieving high quality data in limited time. This data will be important for correlative purposes for LST, it will greatly extend the work begun by Celestcope, and the instrumentation will be useful for further studies of extended sources. Among the latter uses, the search for intergalactic bridges can be mentioned.

High Spatial Resolution Photography: Speed, precision and dynamic range can be obtained by using electronographic and other modern photographic techniques with high performance optical systems. Multi-band observations covering the ultraviolet and visible can provide color-magnitude diagrams of selected open and globular clusters and as-

sociations. These data are important for stellar evolution studies, searches for new variables near the centers of dense clusters, and for investigating fine structure in the interstellar medium in the immediate cluster environs. Precise positions for selected objects can be obtained by high spatial resolution photography. Representative programs include the determination of distances to several clusters, e.g. the Hyades, by the method of trigonometric parallaxes, measurement of the proper motions of classes of objects in order to establish population characteristics, and the measurement of nearly resolved astrometric binaries. For the last case photometric (possibly spectroscopic) classifications for the fainter components may be obtained.

Extended source photographic photometry will provide a means to study the morphology, temperature and density fluctuations in nebular sources. The addition of a Fabry-Perot interferometer would permit the studies to include the dynamic motions of the material.

Calibration and Stellar standards: By taking advantage of the return capability of the Shuttle as well as its liberal size and weight constraints, a program to establish a network of standard stars becomes highly feasible. The use of a sub-satellite in which a standard source is mounted can provide in-situ full aperture calibration with a source observed in the same manner as the stars. A widely spaced network of flux standards can thus

be established for the secondary calibration of instruments located both on the ground and in space (e.g., the LST). Furthermore the basic measurements will provide high quality input for the comparison with detailed, modern, stellar atmosphere models.

High Time Resolution Photometry of Stars: for example, the study of flare stars and pulsars. Such data in the ultraviolet may provide a basis for elaborating pulsar models particularly in those cases where the x-ray and radio data are inconclusive. The capability afforded may also be used profitably to probe the atmosphere of planets by observing stellar occultations. Indeed the same technique is applicable for the study of the earth's atmosphere and hence commonality of instrumentation and general needs with planetary astronomy and aeronomy should be noted. Time resolution of the order of 5 microseconds is considered nominal.

Regular Objectives/Variable Stars: Time resolved ultraviolet photometry and/or spectro photometry can provide information on chromospheric structure and activity in variable stars such as in certain eclipsing variables systems at critical phases.

Stellar Interferometry: In the area of stellar interferometry the absence of atmosphere scintillation improves the signal to noise ratio by improving the coherence of the two channels. Two methods have been considered for the direct

measurement of stellar diameters; the measurement of fringe visibility photoelectrically using widely spaced apertures, and the use of an occulting knife edge. Both require highly specialized instrumentation, critical alignment or adjustment during operation and special data recovery and control techniques. Vibration and general noise of the shuttle may interfere with these experiments.

Far UV Spectroscopy: Grazing incidence instrumentation will be required to investigate the far ultraviolet wavelength region where the spectrum is expected to be dominated by the highly energetic transitions, occurring within stellar coronae. The number of sources sufficiently "bright" or equivalently suffering low absorption by the interstellar medium is unknown at this time.

Extended Nebular Photography: The extended nebular photography requires exceedingly wide fields of view (near 90°). These very fast, but not necessarily large camera systems can search for fossil Stromgren spheres similar to the Gum Nebula and HII regions heated by cosmic rays, study supernova shells for confirmation of blast wave excitation models, and search for extragalactic bridges.

UV Polarimetry: Recent observations with a rocket borne polarimeter have shown that the interstellar medium may exhibit unusual polarimetric properties as a function of wavelength.

Further, circular polarization intrinsic to stars and to the interstellar medium has been detected by ground based instrumentation and is evidence for the interaction of material and intense magnetic fields. This field of renewed and redirected interest, bears directly on our understanding of the interstellar medium.

High Time Resolution Spectroscopy: Recently, time variability in the emission features in some hot stars (Be stars) has been detected on time scales ranging from months down to minutes.